

NASA-MIRS Astrobiology Faculty Incentive Award 2012

Exploring Fischer –Tropsch-Type (FTT) Reaction Mechanism, and the formation of Organics in the Protostellar Nebula, using Iron catalysts as Nebular Dust Analogs

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Summary

This summary presents the results of the three months MIRS Astrobiology Faculty Research Fellowship Summer 2012 at NASA Goddard Spaceflight Center, at the Astrochemistry & Nucleation Laboratory in which I conducted experiments using a combined Fischer-Tropsch type/Haber-Bosch reaction system with multiple iron and iron oxide catalysts as analogs for Nebular Dust. The results of the experiments are discussed, the analysis is already in progress, and further experiments have been proposed, outlined for the extension of the fellowship and the incorporation of minority undergraduate students in the research plan. The results of the experiments are discussed along with implications for understanding the reaction mechanism by which organic compounds originate in the Protostellar Nebula. Through this MIRS summer research experience, I have gained a thorough understanding of the broad interdisciplinary character of astrobiology, NAI's data resource assets, and NASA's unique culture of science and exploration. Furthermore, this fellowship has facilitated the strengthening of astrobiology related curricula, and support NAI research projects at our university, by having an access, and experience to State of the Art laboratories at NAI, and other available NASA resources. The MIRS Faculty Incentive Award will enable us to continue our research project with the Astrochemistry laboratory, with the support of our undergraduate students from our University. The value of the MIRS fellowship for me as junior faculty related to summer experiences with NAI at NASA, with respect to personal and professional development, I also gained a great experience working with the principle investigator, as well as the graduate students (Master Student from the International Space University in France) during their summer internship, which added to my professional development. The most recent models for FTT mechanism explained that many grain surfaces catalyze FTT, and Haber- Bosch (HB) reactions, including iron and magnesium silicates as well as pure silica. Recently Johnson et al. 2008 (PI) has found that as the complex macromolecular carbonaceous deposit builds up on the iron silicate grains, their activity decreases to a small extent, while as this material increases on the surface of much less reactive materials, their catalytic activity increases greatly, as a result of the formation of macromolecular hydrocarbons of organic based coating. Our first aim was to study FTT reaction with different Iron, and Iron oxide catalysts, as substrates, which we have already done this summer. Our second aim is to extract, characterize and analyze these iron substrates, and explore the reaction mechanism of the formation of the initial monolayer of non-soluble and volatile hydrocarbons organic based coatings during FTT reaction, and to investigate the catalytic activity of this monolayer coating to promote the formation of numerous layers on grain surfaces. We plan to apply multiple spectroscopic analysis techniques, such as Fourier transform Infrared spectroscopy (FTIR), Attenuated Total Reflection ATR, Gas Chromatography Mass Spectroscopy (GC/MS, GC/ FID, GC/MS QQQ), in order to characterize, and determine the reaction mechanism of the higher catalytic efficiency of the macromolecular carbonaceous monolayer coating. The PI has extended my access to the laboratory at NASA Goddard in order to continue working on the project with their group. I am also planning to engage two of my

undergraduate students (Annette Butler and Nathaniel Whitt) in the project, and they will be participating in the development of the extraction protocol as well as the analysis of the iron catalysts substrates. The goal of the engagement of my two undergraduate students in the project is to teach them the principles, and new techniques for extraction, isolation, and characterizations of organic compounds that produced in the Protostellar Nebula. Furthermore, the students will also gain a great experience of presenting their data in 44th Lunar and Planetary Science Conference, March 18–22, 2013.

I Proposal Objectives

- 1-** The first objective is to isolate, the organic compounds that formed on the surface of the Iron catalysts. We propose to apply Solid Phase Extraction technique (SPE) for the isolation of the carbonaceous compounds on multiple iron and iron oxide catalysts at different temperatures (200, 300,400,500,600 °C) as analogs for Nebular Dust the FTT reactions.
- 2-** The Second objective is to fully characterize, the organic compounds that formed on the surface of the Iron catalysts. We propose to use EA, FT/IR , ATR, GC/FID , GC/MS , GC/MS QQQ for the Analysis of the carbonaceous compounds of the iron and iron oxide catalysts.
- 3-** The third objective is to determine the rate controlling step of the FTT reaction based on the observation, the spectroscopic characterization of the products, as well as any unidentified hydrocarbons that might form during the course of the reaction, and propose a mechanism of the formation of the molecular hydrocarbons, complexes and determination of the reaction mechanism of the higher catalytic efficiency for the macromolecular carbonaceous coating over the inorganic reducing iron silicate catalysts.

II Method Development

- 1-** Modification of the SPE Solid Phase Extraction technique (SPE) for the isolation of the carbonaceous compounds , that was reported by Daniel Glavin 2006 [1], and Aaron Burton [2] 2012.
- 2-** Characterize the macromolecular complex organic hydrocarbon coating - that deposit on the iron silicate surface -using spectroscopic analysis techniques, such as Elemental analysis (EA) Infrared spectroscopy (FTIR), Liquid Chromatography Mass Spectroscopy (LCMS), at NASA Goddard and, UV/ Vis., Gas Chromatography Mass Spectroscopy (GC/MS) , ATR, GC/FID , GC/MS , GC/MS QQQ for the Analysis of the carbonaceous compounds of the iron and iron oxide catalysts at our research laboratory at Coppin State University.

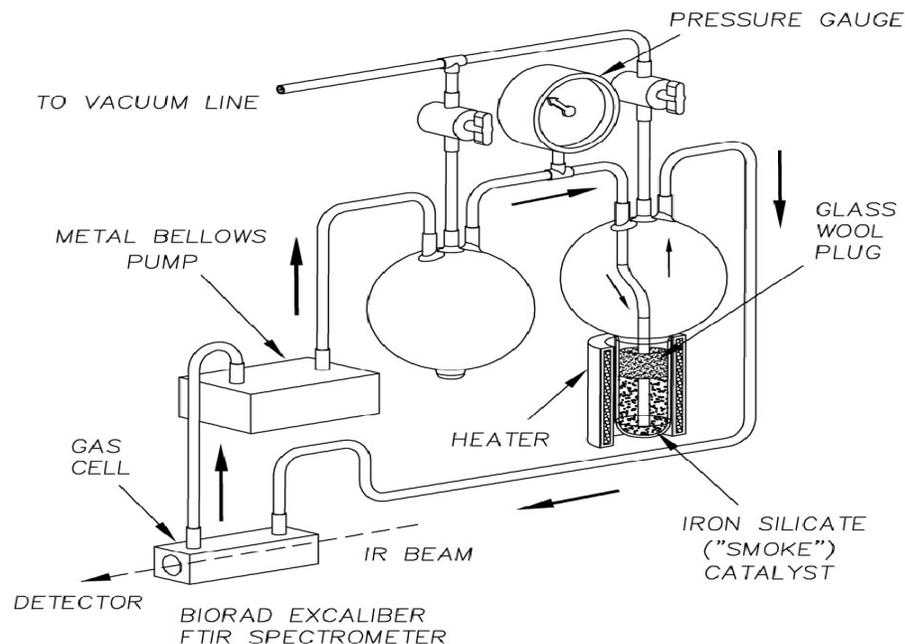


Figure 1 Experimental system for the FTT reaction that proposed to be used to circulate reactive gas mixtures over potential catalysts at controlled temperatures and monitor the changes in the circulating gas via infrared spectroscopy, (Johnson et al 2008) [3].

III- Project Timeline

- 1- The timelines of the proposal matches the duration of the Faculty Incentive Award, since it is a continuation of the fellowship that was completed last August 31, 2012 after the engagement of two of our undergraduate students in the project. We are scheduled to begin on October, 15 2012 following first week of required orientation and end by May 2012.
- 2- The first week is the NASA required safety orientation.
- 3- The second week the students are scheduled for an introduction to the Dust Nucleation Laboratory, at NASA Goddard Space Flight, as well as our research laboratory at Coppin State University
- 4- The third week through the seventh week is the Solid Phase Extraction experiments of the macromolecular hydrocarbons formed during the course of the reaction, and the data collection.
- 5- The eighth week is the student training on the FTT system at NASA Goddard,
- 6- The ninth week is the student training for GCMS system as well as the ATR training at our laboratory at Coppin State University.
- 7- The tenth week, through the end of April 2013, characterization, interpretation, and the processing of the collected data, and Preparing their Poster for Presentation of the data at 44th Lunar and Planetary Science Conference.
- 8- March 18–22, 2013 presenting their data in 44th Lunar and Planetary Science

Conference, March 18–22, 2013.

- 9- First week of May is the preparation of the first draft of the manuscript, from the observation, mechanism and the data collected, and the sketch of reaction mechanism and the conclusion of the research project.

IV- Anticipated Outcome

- 1- Continue research collaboration on a current ongoing project with Dr. Johnson at The Dust Nucleation laboratory at NASA Goddard with focus on the Fischer –Tropsch Type (FTT) catalysis of organic molecules in the Solar Nebula.
- 2- Exposure of undergraduate minority chemistry major students to NASA state of the art laboratories that would enrich their research experience, and exploration skills and interest in continuing astrobiology research.
- 3- Engage student with other scientists at NASA by presenting their data at conferences, and attending seminars, and workshops at NASA Goddard.
- 4- Explore the reaction mechanism of the formation of the initial monolayer non soluble and volatile hydrocarbons organic based coatings during FTT reaction, and to investigate the catalytic activity of this monolayer coating which promote the formation of numerous layers on grain surfaces. This mechanism will provide better understanding of organic chemistry in molecular clouds, and meteorites.
- 5- Prepare manuscript for publication of the collected data and the proposed mechanism, upon the conclusion of the research project.
- 6- Extend the collaboration between Coppin State University research laboratories, and The Dust Nucleation laboratory at NASA Goddard beyond the duration of the Faculty incentive award duration.
- 7- This proposal initiative is the first to engage Coppin State University, with NASA research programs, which will facilitate the participation of our minority students, in research internships, and fellowships with NASA. Additionally this proposal will carry out the University's mission to have high quality research and teaching academic programs that offer innovative curriculum and the latest advancements in research to prepare students for new workforce careers in a global economy.

V- Discussion & Conclusion

The analytical studies of natural materials such as interplanetary dust particles, meteorite components, and presolar grains, are based on the analogs complexes of materials that was synthesized in the laboratory of much more complex natural systems (Nuth et al, 2000, 2002) [3, 4]. This proposal experiments are designed to study a natural process, and the parameters of these reactions are set at different aspects than the actual parameters in nature in order to simulate the natural conditions. The FTT synthesis is an industrial procedure that was developed by Franz Fischer, and Hans Tropsch in the early 19th century for the purpose of obtaining gasoline and liquid fluids from coal by catalytic hydrogenation of a mixture of CO and hydrogen [5]. The FTT chemistry, of the formation of methane by passing a mixture of carbon monoxide

and hydrogen over a reduced catalyst, have led to the observation of carbon monoxide dissociation, and accumulation of hydrocarbon chains on the catalytic surface following polymerization deposition of carbonaceous compounds, such as aliphatic hydrocarbons, water and carbon dioxide[6]. However the origin of the carbonaceous materials in the solar system has not been fully explained and FTT synthesis has been known as a model reaction for production of these organic hydrocarbons in the Solar Nebula[7,8], since the reactants of such reaction as well as the condition were all found in this environment [9]. The expected data from the GC/MS, FTIR, and NMR of this proposed experiment will support the characterization, and the composition of the macromolecular coatings deposited on the iron silicate catalyst, which resemble those found in primitive meteorite matrix, and The determination of the rate controlling step of the formation of the monolayer carbonaceous organic complexes will support the suggested mechanism of the FTT reaction. Furthermore our investigation will lead to the Characterization of the carbonaceous compounds and determination of the reaction mechanism of the higher catalytic efficiency of the macromolecular carbonaceous coating over the inorganic reducing iron silicate catalysts.

VI- References

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